Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

C S A S | *S C C S*

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2003/033 | **Document de recherche 2003/033**

Not to be cited without permission of the authors * | Ne pas citer sans autorisation des auteurs *

Review of the Year 2002 Return of Barkley Sound Sockeye Salmon and Forecasts for 2003

Bilan des remontées de saumon rouge dans la baie Barkley en 2002 et prévisions pour 2003

K. Hyatt, W. Luedke, P. Rankin, J. Till and D. Lewis

Fisheries and Oceans Canada
Stock Assessment Division
Nanaimo, B.C. V9T 6N7

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

This document is available on the Internet at:

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1499-3848 (Printed)

© Her Majesty the Queen in Right of Canada, 2003
© Sa majesté la Reine, Chef du Canada, 2003

Canada

104-01081/

Abstract:

Returns of Barkley Sound sockeye have exceeded the long term average return of 820,000 adults for the past two years (Fig. 2). Although variable, recent returns reflect the continuation of a pattern of predictable variations in ocean climate and survival conditions for juvenile sockeye salmon that have lead to repeated "crashes" (1978, 1985-86, 1989-90, 1994-95) followed within 1-4 years by recoveries (1979-81, 1987-88, 1991-93, 1996-98) of WCVI sockeye returns. The prolonged interval of sub-average returns between 1994 and 2000 ended as anticipated in 2001 as ocean climate signals suggested increased marine survival rates for Barkley Sound sockeye smolts migrating seaward during the 1998-2000 interval.

Over the past 15 years, four independent techniques have been tested for their utility in generating reliable pre-season forecasts of Barkley Sound sockeye returns for harvest managers. The four techniques are known as the Salinity Survival Method (SSM), the Survival Stanza Method (SStM), the Sibling Age Class Method (SACM), and the Salmonid Enhancement Program Biostandard Method (SEPB). Updates on the performance of three of these techniques in the year 2002 are as follows:

(1) The SStM forecast exhibits the best overall performance by far with a mean absolute percent error (MAPE) value of 28% over the most recent 15 years of forecasting (Table 5). SStM forecasts exhibit a statistically significant association with returns among all years (returns in thousands = 1.14•SStM forecast in thousands + 55.19, $R^2 = 0.45$, $p<0.01$). They also account for the majority of variations in returns if the extreme observation associated with the 1991 return year (*when all forecasts techniques underestimated returns*) is omitted from the analysis (returns in thousands = 1.07•SStM forecast in thousands + 21.71, $R^2 = 0.79$, $p<0.001$).

(2) The SEPB forecast exhibited the second best performance in predicting sockeye returns in 2002 (MAPE = 28% , Table 4). However, to achieve a statistically significant association with returns among years, the extreme observation associated with the 1991 return year must be omitted from the analysis (returns in thousands = 1.36•SEPB forecast in thousands – 462.57, $R^2 = 0.49$, $p< 0.01$). Further, during the 1988-2002 testing interval, SEPB forecasts exhibited a much higher MAPE value (58%) than that displayed by SStM forecasts (28%). Because large magnitude deviations between SEPB forecasts and actual returns tend to occur in consecutive years, it is viewed as having limited utility by both harvest managers and fishermen.

(3) The SSM forecast rivalled the SStM forecast in performance between the 1988-1999 testing interval (Hyatt et al. 2000). However, SSM forecasts have overestimated total returns of Barkley Sound sockeye by 490% , 83% and 51% during the years 2000, 2001 and 2002 respectively (Table 4). Thus, SSM forecasts now exhibit a MAPE that averages 68%. SSM forecasts do not exhibit a statistically significant association with returns among all years but do achieve significance if the extreme observation associated with the 1991 return year (*when all forecasts techniques underestimated returns*) is omitted from the analysis (returns in thousands = 0.35 •SSM forecast in thousands + 317, $R^2 = 0.28$, $p<0.05$).

Forecasts of Barkley Sound sockeye returns provided by different models vary greatly for 2003. Midpoint forecast estimates range from a low of 894,000 (SEPB model) to a high of 3,219,000 (SSM model) Barkley Sound sockeye of all ages (Table 13a). Comparative performance of the various forecast options, along with DFO's recent pursuit of a more risk averse approach to management recommends initial adoption of the SStM forecast range. Thus, 618,633 (75% probability) to 1,236,150 (25% probability) "adult" sockeye (i.e. excludes "jacks", Table 13b) constitute the preferred, pre-season forecast range for the year 2003. Supplementary information from coho leading indicator observations suggests that returns are likely to be closer to the upper than the lower end of this range.

Résumé

Les remontées de saumon rouge dans la baie Barkley ont dépassé la moyenne à long terme de 820 000 adultes au cours des deux dernières années (figure 2). Quoique variables, les remontées récentes reflètent un patron de variations prévisible du climat océanique et des conditions influençant la survie des juvéniles qui ont mené à des « effondrements » répétés des remontées (1978, 1985-1986, 1989-1990, 1994-1995), suivies de rétablissements en-deçà de un à quatre ans (1979-1981, 1987-1988, 1991-1993, 1996-1998) des remontées de saumons rouges sur la côte ouest de l'île de Vancouver. La longue période (1994 à 2000) de remontées inférieures à la moyenne a pris fin en 2001, comme le laissaient prévoir les indicateurs du climat océanique d'intérêt pour la survie en mer des smolts de la baie Barkley qui ont migré en mer entre 1998 et 2000.

Au cours des 15 dernières années, la performance de quatre méthodes indépendantes de prévision des remontées de saumon rouge dans la baie Barkley a été évaluée pour la gestion de la pêche. Ces quatre méthodes, appliquées avant l'ouverture de la saison de pêche, sont la méthode de survie en mer (*SSM*), la méthode des stades de survie (*SStM*), la méthode des classes d'âge de la fratrie (*SACM*) et la méthode des normes biologiques du Programme de mise en valeur des salmonidés (*SEPB*). Le bilan de la performance de trois d'entre elles en 2002 suit :

(1) Les prévisions SStM affichent de loin la meilleure performance générale, l'erreur moyenne absolue en pourcentage (EMAP) pour les 15 dernières années se chiffrant à environ 28 % (tableau 5). Elles présentent un rapport statistiquement significatif avec les remontées pour toutes les années (remontée en milliers = 1,14 • prévision SStM en milliers + 55,19, $R^2 = 0,45$, $p < 0,01$). Elles expliquent aussi la majeure partie des variations des remontées lorsque la valeur extrême de l'année 1991 (*toutes les méthodes avaient alors sous-estimé la remontée*) est omise des analyses (remontée en milliers = 1,07 • prévision SStM en milliers + 21,71, $R^2 = 0,79$, $p < 0,001$).

(2) La deuxième meilleure prévision pour 2002 a été fournie par la méthode SEPB (EMAP = 28 % , tableau 4). Toutefois, pour que le rapport avec les remontées réelles pour toutes les années soit statistiquement significatif, il faut omettre la valeur extrême de 1991 (remontée en milliers = 1,36 • prévision SEPB en milliers – 462,57, $R^2 = 0,49$, $p < 0,01$). De plus, pour l'intervalle d'évaluation 1988-2002 utilisé, l'EMAP des prévisions SEPB est beaucoup plus élevée (58 %) que celle des prévisions SStM (28 %). Comme les écarts

importants entre les prévisions SEPB et les remontées réelles ont tendance à se produire lors d'années consécutives, les gestionnaires et les pêcheurs considèrent ces dernières comme étant d'une utilité limitée.

(3) Entre 1988 et 1999, la performance de la méthode SSM a rivalisé avec celle de la méthode SStM (Hyatt *et al.*, 2000). Toutefois, en 2000, 2001 et 2002, la méthode SSM a sous-estimé la remontée totale du saumon rouge dans la baie Barkley de 490%, 83% et 51 % respectivement (tableau 4). Son EMAP atteint maintenant 68 %. Pour l'ensemble de la période, les prévisions SSM ne démontrent pas de correspondance statistiquement significative avec les remontées réelles sauf si la valeur extrême de 1991 (*toutes les méthodes avaient alors sous-estimé la remontée*) est omise des analyses (remontée en milliers = 0,35 • prévision SSM en milliers + 317, $R^2 = 0,28$, $p < 0,05$).

Pour 2003, les prévisions de la remontée de saumon rouge dans la baie Barkley fournies par les différents modèles divergent considérablement. Les valeurs centrales des prévisions vont de 894 000 (modèle SEPB) à 3 219 000 (modèle SSM) saumons rouges de tous âges (tableau 13a). Compte tenu de la performance des diverses méthodes de prévision et de l'approche plus prudente de gestion que privilégie actuellement le MPO, il est recommandé d'adopter initialement la fourchette indiquée par la méthode SStM. Pour la gestion, cette fourchette de prévision recommandée avant la saison 2003 est donc de 618 633 (probabilité de 75 %) à 1 236 150 (probabilité de 25 %) saumons rouges « adultes » (excluant les unibermarins, tableau 13b). Toutefois, des renseignements supplémentaires provenant de l'observation des indicateurs avancés pour le coho donnent à penser que la remontée sera plus près du haut que du bas de cette fourchette.

Introduction:

Detailed summaries of stock status, stock assessment methodologies and forecasting procedures for Barkley Sound sockeye have been presented as PSARC working papers subjected to peer review on several occasions in recent years (Hyatt 1986, Hyatt and Steer 1988; Hyatt and Heizer 1989; Hyatt et. al. 1994, Hyatt and Luedke 1995, 1996, 1998; Hyatt et al. 2000, 2001). The purpose of the present document is to provide a brief update focused on: (i) an appraisal of the performance of the year 2002 forecasts relative to estimates of actual returns, (ii) provision of return year 2003 forecasts and (iii) commentary on the implications of (i) and (ii) for year 2003 harvest planning. Readers interested in detailed descriptions of stock histories, data sources, field survey methods or development of analytical procedures are encouraged to consult earlier papers cited above.

Here briefly, three Barkley Sound sockeye stocks (Great Central, Sproat and Henderson) are managed within a set of mixed-stock, mixed-gear fisheries operating in Area 23 (Steer et. al. 1986; Hyatt and Steer 1987) on the west coast of Vancouver Island (Fig. 1). Great Central and Sproat Lake sockeye originate from the Somass River watershed at the head of Alberni Inlet. Henderson Lake supports the third sockeye stock and is located at the outer end of Alberni Inlet. The migration of the Somass River stocks into Alberni Inlet begins about June 1 and continues until mid August with a peak about July 10. Migration into the river may be delayed by environmental conditions (Steer and Hyatt 1987), causing the timing of the tail of the run into the Somass River to extend into October. The return timing of Henderson Lake sockeye to Alberni Inlet is currently assumed to be about three weeks later than the Somass stocks, although timing of entry into the Henderson River and the Clemens Creek spawning grounds is more variable and dependent on water flows. Spawning occurs on beaches and in tributaries of the lakes in late October to late November.

The long term average target escapement is 350,000 for the Somass system, including 200,000 for Great Central Lake and 150,000 for Sproat Lake. The target escapement for Henderson Lake is 50,000. The escapement into Great Central Lake and Sproat Lake has averaged 364,000 sockeye during the period 1977 to 2001 with a range from a low of 169,000 in 1995 to a high of 786,000 in 2001 (Table 1). The average escapement into Henderson Lake and Clemens Creek during the same interval was 28,343 ranging from a low of 3,000 in 1995 to a high of 120,000 in 1993. The average annual total return of Barkley Sound sockeye during the period 1979 to 1998 was 829,000 with a range of 200,000 to 1,800,000 [annual total returns are sums of year-specific total escapement (Table 1) and catch (Table 2)].

Barkley Sound sockeye stocks support First Nations food, social, and ceremonial needs, First Nations "pilot sales" fisheries, sport fishing, and commercial fisheries. The average annual catch was approximately 413,178 sockeye during the period 1977 through 2001. Since 1995, Somass River sockeye have been managed for a variable harvest rate increasing with abundance from 10% at run sizes above 200,000 to a maximum of 67% at 1.8 million (See Appendix 1). No fisheries, other than assessment requirements, are permitted below 200,000 sockeye. The management of the fisheries targeting these stocks is structured to avoid Henderson Lake sockeye when the forecast of their returns is below the target escapement.

Review of Year 2002 Returns of Somass River Sockeye:

Total returns of approximately 1,115,000 sockeye to Barkley Sound in 2002 achieved 135% of the most recent twenty year average (829,000) and marks the second year of above average returns (Fig. 2) anticipated as marine conditions shifted to favour higher juvenile survivals in the 1999-2000 smolt years. A total catch of 593,584 sockeye was taken in 2002 divided among food and pilot sales by Indian Bands (140,930 sockeye), commercial gillnet and trollers (183,453 sockeye), recreational fisheries (59,309 sockeye) and test fishery catch (9,452 sockeye). Total catch in 2002 was the highest observed in the past nine years and represents 144% of the most recent twenty-five year average (1977-01, Table 2). Increased catches in 2002 were spread among all stakeholder groups (Table 3) who exerted an overall exploitation rate of 53%.

Barkley Sound escapements in 2002 totalled 521,387 sockeye comprised of 220,189 Sproat Lake and 284,854 Great Central Lake fish. Cumulative counts of sockeye at the Henderson River fence indicated 16,344 adult sockeye entered Henderson Lake in 2002 (Jim Lane, Nuu-chah-nulth Tribal Council, pers. comm). This estimate may be biased low because counts at the fence do not cover the full period of migration. No estimate was obtained through direct counts of adults on the spawning grounds due to a fall drought that delayed sockeye entry into Clemens Creek followed by prolonged flood conditions that rendered the usual spawning ground enumerations impossible in 2002. Regardless, the entry of more than 16,000 adults into Henderson Lake in 2002 represents a marked improvement over the numbers observed in the system in 2001 (Table 1).

2002 Forecast Performance:

Three independent techniques were used to generate year 2002 return forecasts for Barkley Sound sockeye (Hyatt et al. S2002-06). These were:

(1) Survival stanza method (SStM): the SStM forecast was for returns of 968,415 sockeye of all ages (843,340 excluding "jacks") to Barkley Sound in 2002.

(2) Sea survival/salinity method (SSM): the SSM forecast was for returns of 1,681,011 sockeye to Barkley Sound in 2002.

(3) Salmon Enhancement Biostandard Method (SEPB): the SEPB forecast was for returns of 871,576 sockeye to Barkley Sound in 2002.

All forecasts suggested that total returns in 2002 would increase steeply to exceed the twenty year average of 820,000 sockeye. Thus, the prolonged interval of sub-average returns observed between 1994 and 2000 (Fig. 2) was anticipated to end in 2001 and to continue in 2002 as ocean climate signals suggested increases in marine survival rates for Barkley Sound sockeye smolts migrating seaward during the 1998-2000 interval (Hyatt et al. S2001-14, S2002-06, unpublished data). Forecasts provided by different models ranged from a low of 871,576 (SStM model forecast excluding "jacks") to a high of 1,203,224 adult sockeye (SSM model).

Two of the forecasts rely on marine temperature (SStM) and marine salinity (SSM) conditions as alternate indicators of future survival prospects for juvenile sockeye salmon. These indicators commonly co-vary such that both predict similar changes in the direction and magnitude of sockeye returns. This was clearly the case in the spring of 1999 and 2000 when both temperature and salinity conditions along the west coast of Vancouver Island signalled a shift to higher marine survival rates that would affect year 2001 and 2002 returns. Given the comparative performance of the various forecast options up to the year 2001 and DFO's recent pursuit of a more risk averse approach to manageme nt, PSARC recommended the SStM forecast range of 754,000 (75% probability) to 1,101,000 (25% probability) sockeye as the preferred, pre-season forecast for 2002. Further, supplementary information from coho leading indicator observations suggested that returns would likely be closer to the upper than the lower end of this range (Hyatt et al. S2002-06).

Approximately 1.1 million sockeye returned to Barkley Sound in 2002 such that observed returns achieved 115% of the SStM forecast, 128% of the SEPB and 66% of the SSM forecasts (Table 4). Thus, all forecast methods correctly anticipated a significant increase in stock size between 2000 and 2002 but the SStM and SEPB forecasts provided the most reliable estimates of returns in 2002 (Table 5).

Return Year 2003 Forecasts:

The same forecast techniques (SStM, SSM and SEPB: methodological details in Hyatt and Luedke 1995) applied in recent years (1987-2002) have been employed to generate return forecasts for 2003.

(1) Survival stanza method (SStM): Adult sockeye returns to Barkley Sound in 2003 will be derived from a 2000 cohort of 18.10 million smolts, returning as 1.3's and 2.2's, and a larger year 2001 cohort of 24.33 million smolts, returning as 1.2's (Table 6,7). Marine temperature conditions at Amphitrite Point during the period of seaward migration (March-May) by smolts exhibited values relative to the 53 year mean of 9.38^{o}C that were first slightly above average (2000, 9.6^{o}C) and then below average (2001, 9.1^{o}C) respectively. These observations suggest that both the 2000 and year 2001 smolt cohorts generating the majority of year 2003 returns should be assigned the higher marine survival rate (5.0%) permitted under SStM forecasts (Hyatt and Luedke 1995). Application of this rate to the 2000 and 2001 smolt cohorts produces an SStM forecast of 993,420 sockeye of all ages (991,820 excluding "jacks") in 2003 (Table 13).

(2) Sea survival/salinity method (SSM): Given the magnitude of smolt releases and salinity conditions that suggest a return to high marine survival rates in both 2000 and 2001 (Table 8), the SSM forecast is for returns of 3,218,820 sockeye to Barkley Sound in 2003 (i.e. the sum of returns for Great Central, Sproat and Henderson in Tables 9 and 10).

(3) SEP Biostandard Method (SEPB): Cohorts of 18.10 million smolts (returning as 1.3's and 2.2's) and 24.33 million smolts (returning as 1.2's) entered Barkley Sound in 2000 and 2001 respectively. Application of a 4.5% SEP biostandard survival rate to these smolts produces a

SEPB forecast of 894,080 sockeye to Barkley Sound in the year 2003 (i.e. the sum of returns for Great Central, Sproat and Henderson in Tables 11 and 12).

Discussion:

Over the past 15 years, four independent techniques have been tested for their utility in generating reliable pre-season forecasts of Barkley Sound sockeye returns for harvest managers. The four techniques are known as the Salinity Survival Method (SSM), the Survival Stanza Method (SStM), the Sibling Age Class Method (SACM), and the Salmonid Enhancement Program Biostandard Method (SEPB). Updates on the performance of three of these techniques to the end of year 2002 are as follows:

(1) The SStM forecast exhibits the best overall performance by far with a mean absolute percent error (MAPE) value of 28% over the most recent 15 years of forecasting (Table 5). SStM forecasts exhibit a statistically significant association with returns among all years (returns in thousands = 1.14•SStM forecast in thousands + 55.19, $R^2 = 0.45$, $p<0.01$). They also account for the majority of variations in returns if the extreme observation associated with the 1991 return year (when all forecasts techniques underestimated returns) is omitted from the analysis (returns in thousands = 1.07•SStM forecast in thousands + 21.71, $R^2 = 0.79$, $p<0.001$).

(2) The SEPB forecast exhibited the second best performance in predicting sockeye returns in 2002 (MAPE = 28%, Table 4). However, to achieve a statistically significant association with returns among years, the extreme observation associated with the 1991 return year must be omitted from the analysis (returns in thousands = 1.36•SEPB forecasts in thousands – 462.57, $R^2 = 0.49$, $p< 0.01$). Further, during the 1988-2002 testing interval, SEPB forecasts exhibited a much higher MAPE value (58%) than that displayed by SStM forecasts (28%). Because large magnitude deviations between SEPB forecasts and actual returns tend to occur in consecutive years, it is viewed as having limited utility by both harvest managers and fishermen.

(3) The SSM forecast rivalled the SStM forecast in performance between the 1988-1999 testing interval (Hyatt et al. 2000). However, SSM forecasts have overestimated total returns of Barkley Sound sockeye by 490%, 83% and 51% during the years 2000, 2001 and 2002 respectively (Table 4). Thus, SSM forecasts now exhibit a MAPE that averages 68%. SSM forecasts do not exhibit a statistically significant association with returns among all years but do achieve significance if the extreme observation associated with the 1991 return year (when all forecast techniques underestimated returns) is omitted from the analysis (returns in thousands = 0.35•SSM forecast in thousands + 317, $R^2 = 0.28$, $p<0.05$).

The SStM and SEPB forecast alternatives indicate that year 2003 returns for Barkley Sound sockeye will be above the long term average and similar in magnitude to those observed during 2002 (Table 13 and Fig. 2). By contrast, the SSM forecast suggests a record return of more than 3 million sockeye. This large magnitude return is principally driven by the extrordinary 19.1% smolt-to-adult marine survival prediction associated with the 2001 smolt year (Table 8). This prediction is unlikely to be reliable given a position well outside of the range of any

historic observations. Comparisons of the various forecast options over the full testing interval from 1988-2002 indicates that the SStM forecast has performed better than alternative forecast models and especially so in recent years. Accordingly, the authors recommend that the Salmon Subcommittee of PSARC adopts the SStM forecast of returns for 2003 (Table 13) bounded by the 25 to 75% probability range that the actual run size will exceed the SStM forecast. Sockeye "jacks" (i.e. age 3 fish) may make a significant contribution to total returns of salmon but are generally not harvested by Barkley Sound fisheries. Thus, SStM forecast values for returns of sockeye of all ages (Table 13a) and excluding jacks (Table 13b) are both provided.

Coho Leading Indicator (CLI) Observations:

Hyatt et al. (2000) identified the existence of a relationship between marine survival variations for Robertson Creek coho and annual return deviations exhibited by Barkley Sound sockeye. These coho leading indicator (CLI) observations were incorporated into our year 2000 and 2001 forecast documents to suggest whether returns would fall closer to the lower or higher end of a range of predicted values. Given the potential utility of CLI observations, we refer to them here for their relevance to year 2003 forecast values.

The CLI is based on the observation that changes in marine survival variations for both juvenile sockeye and coho migrating through Barkley Sound and up the west coast of Vancouver Island may be expected to co-vary. This is because both species face similar changes in physical and biological conditions (changes in abundance of planktonic prey or predators) at sea entry in a given year. Further, because virtually all Robertson Creek coho return as adults a year in advance of the sockeye they migrated seaward with, empirical observations of smolt-to-adult survival levels for a given brood year of coho are available one year in advance of those of sockeye originating from the same brood year. Accordingly, coho survival values observed in year n may anticipate survival values or return deviations to be exhibited by sockeye in year n+1.

Analysis of recent year observations of sockeye smolt-to-adult survival variations are still incomplete. However, a preliminary examination of whether coho survival variations may serve as a leading indicator of the following year's sockeye returns is possible based on a comparison of annual returns. Year n deviations of Robertson Creek coho from their 24-year mean smolt-to-adult survival value (Table 14) are compared with year n+1 deviations by sockeye from their 23- year mean of total returns (Tables 1 & 2). Relationships based on analysis of observations from the full period of record (the CLI based on the 25 brood years from 1972 to 1996) as well as the latter half of this interval (the CLI based on 13 brood years from 1984 to 1996) were both highly significant (Table 15). Thus, the coho leading indicator of sockeye returns appears to have some utility. Smolt-to-adult survival of 1999 Robertson Creek brood year coho was 9.6% (D. Dobson, pers comm). Thus, values for the CLI_{25} (1,060,300) and CLI_{13} (1,716,300) observations (Table 15.) constitute supplementary evidence that returns in 2003 will be similar to those observed in 2002 in that they will likely be closer to the upper end (i.e. 1,236,150) rather than the lower end (618,633) of the SStM range of predicted values.

Beginning in 1995, DFO established an "in-season" management benchmark of escapement of 200,000 Somass sockeye to satisfy biological conservation objectives (Appendix, Attachment

1, Tousignant to Eidsvik, Oct.4, 1995 in Hyatt and Luedke 1995). Accordingly, fisheries managers are committed to eliminating or avoiding exploitation of Somass sockeye when either pre-season or in-season abundance indicators suggest stock sizes of 200,000 or less. The recommended SStM forecast suggests that returns of sockeye to Barkley Sound in the year 2003 have a greater than 90% probability of being above the 200,000 escapement benchmark. Given the variable harvest rate strategy adopted in 1996 (Anonymous 1996 and Appendix 1), harvest projections under the SStM forecast will range from a total allowable catch (TAC) of more than 200,000 sockeye given an SStM return of 618,633 (75% probability for returns of sockeye adults to the Somass) to a TAC of 700,000 given an SStM return of 1,236,150 (25% probability for returns of adult sockeye to the Somass).

Recommendations:

(1) We recommend an SStM forecast range of 618,633-1,236,150 sockeye as a conservative, risk averse range of expected adult returns to Barkley Sound in 2003. However, there is some evidence that returns are likely to be closer to the upper than the lower end of this range (i.e. CLI leading indicator observations anticipate this).
(2) The current forecast update is to be followed by a new working paper on Barkley Sound sockeye stock status and forecast methods to be reviewed at the May PSARC meeting of the Salmon Subcommittee. Consequently, recommendations presented here may be subject to revision pending the outcome of the May meeting.

References:

Anonymous. 1996. Overview of Alberni Inlet sockeye management: 1996 pre-season planning for Alberni Inlet sockeye. Unpublished document. Department of Fisheries and Oceans, South Coast Division, Stevenson Point Road, Nanaimo, B.C. 9 p.

Hyatt, K. D. 1986. Advice on Barkley Sound sockeye. PSARC Advisory Document S86-6: 11p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D. and G. J. Steer. 1987. Barkley Sound sockeye salmon (*Oncorhynchus nerka*): Evidence for over a century of successful stock development, fisheries management, research, and enhancement efforts. Can. Spec. Publ. Fish. Aquat. Sci. 96: 435-457.

Hyatt, K. D. and G. J. Steer. 1988. Stock status and 1988 forecasts of Barkley Sound sockeye. PSARC Working Paper S88-2. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D. and S. Heizer. 1989. Stock status and 1990 forecasts of Barkley Sound sockeye. PSARC Annual Update S90-19. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D., W. Luedke, D. P. Rankin, and L. Gordon. 1994. Review of 1988-1994 forecast performance, stock status and 1995 forecasts of Barkley Sound sockeye. PSARC Working Paper S94-21. 18 p. plus appendices. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D.and W. Luedke. 1995. Review of 1988-1995 forecast performance, stock status and 1996 forecasts of Barkley Sound sockeye. PSARC Working Paper S95-13. 57 p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D. and W. Luedke. 1996. An update on 1996 stock status and 1997 forecasts of Barkley Sound sockeye. PSARC Working Paper S96-21. 38 p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D. and W. Luedke. 1998. An update on 1997 stock status and 1998 forecasts of Barkley Sound sockeye. PSARC Working Paper S98-4. 33 p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B.C.

Hyatt, K. D., W. Luedke, J. Till, D. P. Rankin and D. Lewis. 2000. Review of the 1999 return of Barkley Sound sockeye salmon and forecasts for 2000. PSARC Working Paper S2000-06. 29 p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B. C.

Hyatt, K. D., W. Luedke, J. Till, D. P. Rankin and D. Lewis. 2001. Review of the year 2000 return of Barkley Sound sockeye salmon and forecasts for 2001. PSARC Working Paper S2001-14. 30 p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B. C.

Hyatt, K. D., W. Luedke, J. Till, D. P. Rankin and D. Lewis. 2002. Review of the year 2001 return of Barkley Sound sockeye salmon and forecasts for 2002. PSARC Working Paper S2002-06. 30 p. Unpublished report, Department of Fisheries and Oceans, Stock Assessment Division, Pacific Biological Station, Nanaimo, B. C.

Steer, G. J., N. B. F. Cousens, H. Stiff and K. D. Hyatt. 1986. An analysis of gear selectivity and sources of bias in estimates of age and stock composition of the 1980-1984 Barkley Sound sockeye salmon (*Oncorhynchus nerka*) catch. Can. Tech. Rep. Fish. Aquat. Sci. No 1445. 77 p.

Steer, G. J. and K. D. Hyatt. 1987. Use of a run timing model to provide in-season estimates of sockeye salmon (*Oncorhynchus nerka*) returns to Barkley Sound, 1985. Can. Tech. Rep. Fish. Aquat. Sci. No. 1557: 39 p.

Table 1. Barkley Sound sockeye escapement summary

Year	Total	Henderson	Great Central	Sproat
1977	297800	4800	212200	80800
1978	158900	7000	114400	37500
1979	360441	20000	263995	76446
1980	318736	20760	159597	138379
1981	430191	40354	262287	127550
1982	470261	56065	172269	241927
1983	644987	44987	350000	250000
1984	267524	45122	133306	89096
1985	299719	25000	127758	146961
1986	316361	5000	118420	192941
1987	435969	29000	255153	151816
1988	460265	30000	194848	235417
1989	425401	38000	219414	167987
1990	323910	35000	176850	112060
1991	698470	50000	437172	211298
1992	429416	27000	191154	211262
1993	540809	120000	238094	182715
1994	265346	15138	106706	143502
1995	169293	3000	63893	102400
1996	325123	21000	120173	183950
1997	321036	21000	174063	125973
1998	452921	30000	236043	186878
1999	392353	4412	215089	172852
2000	216118	16000*	75534	124584
2001	785740	3633*	410589	371518
2002	521387	16344*	284854	220189

* preliminary estimate subject to change for Henderson final.

Table 2. Annual catch of Barkley Sound sockeye by stock* and year

			% of Total by Stock		
Year	Total	Exploitation Rate	Henderson	Great Central	Sproat
1977	1101211	0.78			
1978	185100	0.54			
1979	727725	0.67			
1980	642800	0.67	4.4	52.7	42.8
1981	919000	0.68	2.9	59.1	38.1
1982	410000	0.47	2.1		
1983	860000	0.57	4.6	55.3	40.1
1984	914602	0.77	5.2	59.7	35.2
1985	367000	0.55	1.8	58.8	39.4
1986	30000	0.06	0	38.1	61.9
1987	199696	0.38	15.4	58.5	26.1
1988	389397	0.42	10.9	32.6	56.5
1989	35000	0.07	8.93	51.58	39.49
1990	30000	0.08	10.81	54.6	34.6
1991	1121675	0.62	5	58.5	35.5
1992	567377	0.57	13.9	34.7	51.4
1993	738265	0.58	15.4	50.3	34.3
1994	200000	0.43			
1995	30000	0.15			
1996	55000	0.14			
1997	144201	0.31			
1998	206824	0.33			
1999	117000	0.23			
2000	105864	0.35			
2001	231729	0.23			
2002	593584	0.53			

*sockeye stocks from Great Central, Sproat and Henderson Lakes contribute to Barkley Sound annual catch. Between 1980 and 1993 catch mixtures were allocated to stock of origin on the basis of unique combinations of parasites serving as "stable" natural tags. However, use of the technique was discontinued after 1993 because parasite infection rates were found to be unstable among stocks towards the end of the series.

Table 3. Summary of sockeye catch (by area and gear) and escapement (total by stock and by age) during the summer and fall of the year 2002.

A. Alberni Inlet	Sockeye total for all ages	Total Sockeye by Age 1.1	1.2	1.3	2.1	2.2	2.3
Seine Test Fishery	6,502	1	2,414	2,407	0	875	678
Somass "Food" Seine	36,054	0	14,605	15,375	85	3,202	2,787
Somass "Food" Gillnet	62,960	0	21,822	29,243	0	5,942	5,952
Nu-cha-nulth Seine	34,416	220	12,757	10,873	25	6,211	4,330
Alberni Inlet Sport	55,544	518	24,050	20,439	73	6,526	3,938
Papermill Dam Sport	3,765	0	1,054	1,581	0	602	527
Alberni Inlet Troll	51,550	407	21,628	19,189	55	6,418	3,853
Alberni Inlet Seine	203,500	423	89,632	59,609	1,199	33,694	
Total Inside	**454,291**	**1,570**	**187,963**	**158,715**	**1,438**	**63,450**	**18,963**
B. Outer Alberni and Barkley Sound							
Seine Test Fishery	2,950	9	1,289	1,080	9	320	144
Native - "Section 35"	3,000	22	1,291	957	22	508	199
Commercial Gillnet	131,903	727	48,988	46,446	0	22,483	13,259
Uchucklesaht Fish	4,500	52	2,328	1,086	0	672	362
Total Outside	**142,253**	**810**	**53,896**	**49,569**	**31**	**23,984**	**13,964**
Total Catch in 2000 (A+B)	**593,584**	**2,379**	**241,859**	**208,284**	**1,469**	**87,435**	**54,992**
C. Preliminary Estimates of Escapement							
Great Central (GC)	284,854	13,932	99,102	94,440	8,266	44,762	24,352
Sproat (SP)	220,189	19,548	144,329	41,189	2,711	11,673	739
Somass Total (GC+SP)	**505,043**	**33,480**	**243,431**	**135,629**	**10,977**	**56,435**	**25,091**

Table 4. Summary of mean absolute percent error (MAPE) of forecasts of returns relative to observed returns.

Return Year	Returns Observed	SSM forecast	SSM Devs (obs-4cst)	SSM Devs as % of Obs
88	850	740	110	12.94
89	460	387	73	15.87
90	354	342	12	3.39
91	1820	668	1152	63.30
92	997	1372	-375	-37.61
93	1279	1229	50	3.91
94	465	792	-327	-70.32
95	200	422	-222	-111.00
96	380	400	-20	-5.26
97	465	693	-228	-49.03
98	660	771	-111	-16.82
99	509	575	-66	-12.97
2000	322	1900	-1578	-490.06
2001	1017	1865	-848	-83.38
2002	1115	1681	-566	-50.76
MAPE				68.44
		SStM	SStM	SStM
88	850	560	290	34.12
89	460	501	-41	-8.91
90	354	479	-125	-35.31
91	1820	653	1167	64.12
92	997	1089	-92	-9.23
93	1279	996	283	22.13
94	530	464	66	12.45
95	200	264	-64	-32.00
96	380	279	101	26.58
97	465	357	108	23.23
98	660	451	209	31.67
99	509	332	177	34.77
2000	322	532	-210	-65.22
2001	1017	907	110	10.81
2002	1115	968	147	13.18
MAPE				28.24
		SEPB	SEPB	SEPB
88	850	1104	-254	-29.88
89	460	790	-330	-71.74
90	354	709	-355	-100.28
91	1820	800	1020	56.04
92	997	959	38	3.81
93	1279	992	287	22.44
94	530	615	-85	-16.04
95	200	565	-365	-182.50
96	380	557	-177	-46.58
97	465	715	-250	-53.76

98	660	903	-243	-36.82
99	509	665	-156	-30.65
2000	322	946	-624	-193.79
2001	1017	1036	-19	-1.83
2002	1115	872	243	27.87
MAPE				58.27

Table 5. A comparison of several attributes of SStM, SSM and SEPB forecasts.

		(a) includes 91		(b) excludes 91		(c)	(d)
Forecast	MAPE	r-square	prob.	r-square	prob.	direction correct	risk rank
SStM	28%	0.45	<0.01	0.78	< 0.01	11 of 14	2
SSM	68%	0.04	0.22	0.28	0.03	8 of 14	3
SEPB	58%	0.21	0.05	0.49	< 0.05	10 of 14	1

(a) analysis includes 15 years of predicted and observed returns

(b) excludes the 1991 return year from analysis when all forecasts failed to anticipate a record return of sockeye to Barkley Sound.

(c) number of times in past 15 years each forecast has correctly identified whether returns would increase or decrease relative to returns the previous year.

(d) year 2002 forecasts are ranked from most to least conservative based on the magnitude of the predicted return i.e. the SEP-B forecast is the lowest of the three in 2002 and thus is considered to be the most conservative or risk averse.

Table 6. SStM predictions of returns by smolt year.

Stock	Smolt year	Release (millions)	Mean SST* from March to May (Celcius)	Deviations from the 30 year mean SST	Temp/ survival pred. %	Adults expected	Adult production expected by smolt year 3's	4's	5's
Great	1986	10.23	9.8	0.42	2.25	230175	16112	126596	80561
Central	1987	6.19	10.3	0.92	2.25	139275	9749	76601	48746
	1988	5.3	9.3	-0.08	5	265000	18550	145750	92750
	1989	7.1	9.27	-0.11	5	355000	24850	195250	124250
	1990	9.09	9.87	0.49	5	454500	31815	249975	159075
	1991	9.7	9.57	0.19	5	485000	33950	266750	169750
	1992	4.8	11	1.62	2.25	108000	7560	59400	37800
	1993	7.6	10.3	0.92	2.25	171000	11970	94050	59850
	1994	4.43	9.77	0.39	2.25	99675	6977	54821	34886
	1995	4.94	9.93	0.55	2.25	111150	7781	61133	38903
	1996	10.02	10.17	0.79	2.25	225450	15782	123998	78908
	1997	4.43	10.1	0.72	2.25	99675	6977	54821	34886
	1998	17.81	10.43	1.05	2.25	400725	28051	220399	140254
	1999	11.95	8.77	-0.61	5	597500	41825	328625	209125
	2000	7.43	9.6	0.22	5	371500	26005	204325	130025
	2001	13.61	9.1	-0.28	5	680500	47635	374275	238175
	2002	3.36	8.9	-0.48	5	168000	11760	92400	58800
Sproat	1986	6.97	9.8	0.42	2.25	156825	25092	98800	31365
	1987	8.3	10.3	0.92	2.25	186750	29880	117653	37350
	1988	9.3	9.3	-0.08	5	465000	74400	292950	93000
	1989	13.2	9.27	-0.11	5	660000	105600	415800	132000
	1990	10.55	9.87	0.49	5	527500	84400	332325	105500
	1991	9.16	9.57	0.19	5	458000	73280	288540	91600
	1992	5.88	11	1.62	2.25	132300	21168	83349	26460
	1993	4.6	10.3	0.92	2.25	103500	16560	65205	20700
	1994	5.99	9.77	0.39	2.25	134775	21564	84908	26955
	1995	6.77	9.93	0.55	2.25	152325	24372	95965	30465
	1996	11.7	10.17	0.79	2.25	263250	42120	165848	52650
	1997	5.87	10.1	0.72	2.25	132075	21132	83207	26415
	1998	8.46	10.43	1.05	2.25	190350	30456	119921	38070
	1999	8.23	8.77	-0.61	5	411500	65840	259245	82300
	2000	8.46	9.6	0.22	5	423000	67680	266490	84600
	2001	9.68	9.1	-0.28	5	484000	77440	304920	96800
	2002	7.48	8.9	-0.48	5	374000	59840	235620	74800
Hen.	1986	4.19	9.8	0.42	2.25	94275	0	48080	46195
	1987	2.02	10.3	0.92	2.25	45450	0	23180	22271
	1988	0.15	9.3	-0.08	5	7500	0	3825	3675
	1989	0.77	9.27	-0.11	5	38500	0	19635	18865
	1990	4.88	9.87	0.49	5	244000	0	124440	119560
	1991	1.08	9.57	0.19	5	54000	0	27540	26460
	1992	0.4	11	1.62	2.25	9000	0	4590	4410

1993	0.7	10.3	0.92	2.25	15750	0	8033	7718
1994	1.62	9.77	0.39	2.25	36450	0	18590	17861
1995	5.46	9.93	0.55	2.25	122850	0	62654	60197
1996	0.33	10.17	0.79	2.25	7425	0	3787	3638
1997	0.05	10.1	0.72	2.25	1125	0	574	551
1998	1.94	10.43	1.05	2.25	43650	0	22262	21389
1999	1.01	8.77	-0.61	5	50500	0	25755	24745
2000	0.05	9.6	0.22	5	2500	0	1275	1225
2001	1.05	9.1	-0.28	5	52500	0	26775	25725
2002	2.13	8.9	-0.48	5	106500	0	54315	521855

* Sea surface temperature (SST) from Amphitrite Point B. C.

Table 7. Barkley Sound sockeye SStM predictions by adult return year.

Stock	Return Year	Adult production expected in fishery by return year			
		3's	4's	5's	Total
Great Central	1989	18550	76601	80561	175712
	1990	24850	145750	48746	219346
	1991	31815	195250	92750	319815
	1992	33950	249975	124250	408175
	1993	7560	266750	159075	433385
	1994	11970	59400	169750	241120
	1995	6977	94050	37800	138827
	1996	7781	54821	59850	122452
	1997	15782	61133	34886	111801
	1998	6977	123998	38903	169878
	1999	28051	54821	78908	161780
	2000	41825	220399	34886	297110
	2001	26005	328625	140254	494884
	2002	47635	204325	209125	413450
	2003	11760	374275	130025	516060
Sproat	1989	74400	117653	31365	223418
	1990	105600	292950	37350	435900
	1991	84400	415800	93000	593200
	1992	73280	332325	132000	537605
	1993	21168	288540	105500	415208
	1994	16560	83349	91600	191509
	1995	21564	65205	26460	113229
	1996	24372	84908	20700	129980
	1997	42120	95965	26955	165040
	1998	21132	165848	30465	217445
	1999	30456	83207	52650	166313
	2000	65840	119921	26415	212176
	2001	67680	259245	38070	364995
	2002	77440	266490	82300	426230
	2003	59840	304920	84600	449360
Henderson	1989	0	23180	46195	69375
	1990	0	3825	22271	26096
	1991	0	19635	3675	23310
	1992	0	124440	18865	143305
	1993	0	27540	119560	147100
	1994	0	4590	26460	31050
	1995	0	8033	4410	12443
	1996	0	18590	7718	26308
	1997	0	62654	17861	80515
	1998	0	3787	60197	63984

1999	0	574	3638	4212
2000	0	22262	551	22813
2001	0	25755	21389	47144
2002	0	1275	24745	26020
2003	0	26775	1225	28000

Table 8. Summary of Amphitrite Point salinity observations and predicted marine survival of sockeye salmon.

Smolt year	Feb.	March	April	May	Mean of Mar-May salinity	Predicted marine survival (as %) *
1972	27.5	25.2	27.9	29.9	27.67	1.04
1973	28.9	29.1	30.4	30.7	30.07	9.67
1974	26.6	27.2	28.1	28.9	28.07	1.51
1975	28.3	28.6	30.1	30.7	29.80	7.55
1976	28.1	27.7	28.8	30.1	28.87	3.17
1977	29.3	28.8	29.1	30	29.30	4.74
1978	28.7	29.5	29.6	30.2	29.77	7.32
1979	28.6	28.3	30.4	30.9	29.87	8.03
1980	28.8	28.1	29.3	30.1	29.17	4.19
1981	28.5	28.6	28.8	29.4	28.93	3.37
1982	27.1	27.9	27.5	30.3	28.57	2.4
1983	28.1	26.9	28.7	29.3	28.30	1.87
1984	28.2	27.7	27.8	28.2	27.90	1.29
1985	29.7	29.8	29.5	29.3	29.53	5.89
1986	28.2	26.5	28.5	28.7	27.90	1.29
1987	27.4	27.6	29	29.9	28.83	3.07
1988	27.8	28.7	28.7	28	28.47	2.19
1989	28.9	28.6	28	30.5	29.03	3.7
1990	28.5	28.4	29.9	31.1	29.80	7.55
1991	26.8	28.6	29.3	30	29.30	4.74
1992	27	29.1	29.7	30.6	29.80	7.54
1993	28.2	29.2	27.9	28	28.37	1.99
1994	28.7	27.5	29.3	30.1	28.97	3.48
1995	26.7	27.7	29.5	31.1	29.43	5.37
1996	28.6	28.6	28.4	30.2	29.07	3.82
1997	28.8	27.8	27.3	28.2	27.77	1.14
1998	28.6	28.9	30.3	31.3	30.17	10.59
1999	28.1	28.3	30	31.1	29.80	7.54
2000	28.8	29.4	30.7	29	29.7	6.89
2001	30.1	30.8	30.7	30.9	30.8	19.1
2002	27.5	29.4	30.0	31.1	30.16	10.59

* % marine survival = smolt-to-adult survival predicted on the basis of a salinity versus survival relationship established by Hyatt (1986).

Table 9. SSM forecasts of adult production by smolt year.

Stock	Smolt year	Release (millions)	Salinity-survival prediction	Total adults expected	Adult production expected by smolt year as 3's	as 4's	as 5's
Great	1984	9.2	1.29	118680	8308	65274	41538
Central	1985	12.35	5.27	650845	45559	357965	227796
	1986	10.23	1.29	131967	9238	72582	46188
	1987	6.19	3.07	190033	13302	104518	66512
	1988	5.3	2.19	116070	8125	63839	40625
	1989	7.1	3.7	262700	18389	144485	91945
	1990	9.09	7.55	686295	48041	377462	240203
	1991	9.7	4.74	459780	32185	252879	160923
	1992	4.8	7.54	361920	25334	199056	126672
	1993	7.6	1.99	151240	10587	83182	52934
	1994	4.43	3.48	154164	10791	84790	53957
	1995	4.94	5.37	265278	18569	145903	92847
	1996	10.02	3.82	382764	26793	210520	133967
	1997	4.43	1.14	50502	3535	27776	17676
	1998	17.81	10.59	1886079	132026	1037343	660128
	1999	11.95	7.54	901030	63072	495567	315361
	2000	7.43	6.89	511927	35835	281560	179174
	2001	13.61	19.1	2599510	181966	1129731	909829
	2002	3.6	10.59	355824	24908	195703	124538
Sproat	1984	11.72	1.29	151188	24190	95248	30238
	1985	19.56	5.27	1030812	164930	649412	206162
	1986	6.97	1.29	89913	14386	56645	17983
	1987	8.3	3.07	254810	40770	160530	50962
	1988	9.3	2.19	203670	32587	128312	40734
	1989	13.2	3.7	488400	78144	307692	97680
	1990	10.55	7.55	796525	127444	501811	159305
	1991	9.16	4.74	434184	69469	273536	86837
	1992	5.88	7.54	443352	70936	279312	88670
	1993	4.6	1.99	91540	14646	57670	18308
	1994	5.99	3.48	208452	33352	131325	41690
	1995	6.77	5.37	363549	58168	229036	72710
	1996	11.7	3.82	446940	71510	281572	89388
	1997	5.87	1.14	66918	10707	42158	13384
	1998	8.46	10.59	895914	143346	564426	179183
	1999	8.23	7.54	620542	99287	390941	124108
	2000	8.46	6.89	582894	93263	367223	116579
	2001	9.68	19.1	1848880	295821	1164794	369776
	2002	7.48	10.59	792132	126741	499043	158426
Hen.	1984	4.75	1.29	61275	0	31250	30025
	1985	3.52	5.27	185504	0	94607	90897
	1986	4.19	1.29	54051	0	27566	26485
	1987	2.02	3.07	62014	0	31627	30387

1988	0.15	2.19	3285	0	1675	1610
1989	0.77	3.7	28490	0	14530	13960
1990	4.88	7.55	368440	0	187904	180536
1991	1.08	4.74	51192	0	26108	25084
1992	0.4	7.54	30160	0	15382	14778
1993	0.7	1.99	13930	0	7104	6826
1994	1.62	3.48	56376	0	28752	27624
1995	5.46	5.37	293202	0	149533	143669
1996	0.33	3.82	12606	0	6429	6177
1997	0.05	1.14	570	0	291	279
1998	1.94	10.59	205446	0	104777	100669
1999	1.01	7.54	76154	0	38839	37315
2000	2.21	6.89	152269	0	77657	74612
2001	1.05	19.1	200550	0	102281	98270
2002	2.13	10.59	225567	0	115039	110528

Table 10. Barkley Sound SSM sockeye predictions by adult return year.

Stock	Return year	Adult production expected in fishery by return year and age			
		3's	4's	5's	Total
Great Central	1990	18389	63839	66512	148740
	1991	48041	144485	40625	233151
	1992	32185	377462	91445	501092
	1993	25334	252879	240203	518416
	1994	10587	199056	160923	370566
	1995	10791	83182	126672	220645
	1996	18569	84790	52934	156293
	1997	26793	145903	53957	226653
	1998	3535	210520	92847	306902
	1999	132026	27776	133967	293769
	2000	63072	1037343	17676	1118091
	2001	35835	495567	660128	1191530
	2002	181966	281560	315361	778887
	2003	24908	1429731	179174	1633813
Sproat	1990	78144	128312	50962	257418
	1991	127444	307692	40734	475870
	1992	69469	501811	97680	668960
	1993	70936	273536	159305	503777
	1994	14646	279312	86837	380795
	1995	33352	57670	88670	179692
	1996	58168	131325	18308	207801
	1997	71510	229036	41690	342236
	1998	10707	281572	72710	364989
	1999	143346	42158	89388	274892
	2000	99287	564426	13384	677097
	2001	93263	390941	179183	663387
	2002	295821	367223	124108	787152
	2003	126741	1164794	116579	1408114
Henderson	1990	0	1675	30387	32062
	1991	0	14530	1610	16140
	1992	0	187904	13960	201864
	1993	0	26108	180536	206644
	1994	0	15382	25084	40466
	1995	0	7104	14778	21882
	1996	0	28752	6826	35578
	1997	0	149533	27624	177157
	1998	0	6429	143669	150098
	1999	0	291	6177	6468
	2000	0	104777	279	105056
	2001	0	38839	100669	139508
	2002	0	77657	37315	114972
	2003	0	102281	74612	176893

Table 11. Summary of SEPB forecasts by smolt-year.

Stock	Smolt Year	Release (millions)	SEP standard survival	Adults expected	Adult production expected by smolt year 3's	4's	5's
Great	1984	9.2	4.5	414000	28980	227700	144900
Central	1985	12.35	4.5	555750	38903	305663	194513
	1986	10.23	4.5	460350	32225	253193	161123
	1987	6.19	4.5	278550	19499	153203	97493
	1988	5.3	4.5	238500	16695	131175	83475
	1989	7.1	4.5	319500	22365	175725	111825
	1990	9.09	4.5	409050	28634	224978	143168
	1991	9.7	4.5	436500	30555	240075	152775
	1992	4.8	4.5	216000	15120	118800	75600
	1993	7.6	4.5	342000	23940	188100	119700
	1994	4.43	4.5	199350	13955	109643	69773
	1995	4.94	4.5	222300	15561	122265	77805
	1996	10.02	4.5	450900	31563	247995	157815
	1997	4.43	4.5	199350	13955	109643	69773
	1998	17.81	4.5	801450	56102	440798	280508
	1999	11.95	4.5	537750	37643	295763	188213
	2000	7.43	4.5	334350	23405	183893	117023
	2001	13.61	4.5	612450	42872	336848	214358
	2002	3.36	4.5	151200	10584	83160	52920
Sproat	1984	11.72	4.5	527400	84384	332262	105480
	1985	19.56	4.5	880200	140832	554526	176040
	1986	6.97	4.5	313650	50184	197600	62730
	1987	8.3	4.5	373500	59760	235305	74700
	1988	9.3	4.5	418500	66960	263655	83700
	1989	13.2	4.5	594000	95040	374220	118800
	1990	10.55	4.5	474750	75960	299093	94950
	1991	9.16	4.5	412200	65952	259686	82440
	1992	5.88	4.5	264600	42336	166698	52920
	1993	4.6	4.5	207000	33120	130410	41400
	1994	5.99	4.5	269550	43128	169817	53910
	1995	6.77	4.5	304650	48744	191930	60930
	1996	11.7	4.5	526500	84240	331695	105300
	1997	5.87	4.5	264150	42264	166415	52830
	1998	8.46	4.5	380700	60912	239841	76140
	1999	8.23	4.5	370350	59256	233321	74070
	2000	8.46	4.5	380700	60912	239841	76140
	2001	9.68	4.5	435600	69696	274428	87120
	2002	7.48	4.5	336600	53856	212058	67320
Hen.	1984	4.75	4.5	213750	0	109013	104738
	1985	3.52	4.5	158400	0	80784	77616
	1986	4.19	4.5	188550	0	96161	92390
	1987	2.02	4.5	90900	0	46359	44541

1988	0.15	4.5	6750	0	3443	3308
1989	0.77	4.5	34650	0	17672	16979
1990	4.88	4.5	219600	0	111996	107604
1991	1.08	4.5	48600	0	24786	23814
1992	0.4	4.5	18000	0	9180	8820
1993	0.7	4.5	31500	0	16065	15435
1994	1.62	4.5	72900	0	37179	35721
1995	5.46	4.5	245700	0	125307	120393
1996	0.33	4.5	14850	0	7574	7277
1997	0.05	4.5	2250	0	1148	1103
1998	1.94	4.5	87300	0	44523	42777
1999	1.01	4.5	45450	0	23180	22271
2000	0.05	4.5	2250	0	1148	1103
2001	1.05	4.5	47250	0	24098	23153
2002	2.13	4.5	95850	0	48884	46967

Table 12. SEPB predictions by adult return year.

Stock	Return year	Adult production expected for fishery by return year			
		3's	4's	5's	Total
Great Central	1988	19499	253193	194513	467205
	1989	16695	153203	161123	331021
	1990	22365	131175	97493	251033
	1991	28634	175725	83475	287834
	1992	30555	224978	111825	367358
	1993	15120	240075	143168	398363
	1994	23940	118800	152775	295515
	1995	13955	188100	75600	277655
	1996	15561	109643	119700	244904
	1997	31563	122265	69773	223601
	1998	13955	247995	77805	339755
	1999	56102	109643	157815	323560
	2000	37643	440798	69773	548214
	2001	23405	295763	280508	599676
	2002	42872	183893	188213	414978
	2003	10584	336848	117023	464455
Sproat	1988	59760	197600	176040	433400
	1989	66960	235305	62730	364995
	1990	95040	263655	74700	433395
	1991	75960	374220	83700	533880
	1992	65952	299093	118800	483845
	1993	42336	259686	94950	396972
	1994	33120	166698	82440	282258
	1995	43128	130410	52920	226458
	1996	48744	169817	41400	259961
	1997	84240	191930	53910	330080
	1998	42264	331695	60930	434889
	1999	60912	166415	105300	332627
	2000	59256	239841	52830	351927
	2001	60912	233321	76140	370373
	2002	69696	239841	74070	383607
	2003	53856	274428	76140	404424
Henderson	1988	0	96161	77616	173777
	1989	0	46359	92390	138749
	1990	0	3443	44541	47984
	1991	0	17672	3308	20980
	1992	0	111996	16979	128975
	1993	0	24786	107604	132390
	1994	0	9180	23814	32994
	1995	0	16065	8820	24885
	1996	0	37179	15435	52614

1997	0	125307	35721	161028
1998	0	7574	120393	127967
1999	0	1148	7277	8425
2000	0	44523	1103	45626
2001	0	23180	42777	65957
2002	0	1148	22271	23419
2003	0	24098	1103	25201

Table 13. Barkley Sound sockeye year 2003 return forecast summary.

Probabiiity of Achieving Specified Run*

a. All

Forecast	25%	50%	75%	90%
SStM	1,303,750	**993,420**	666,585	648,007
SEPB	928,144	**894,080**	644,900	519,013
SSM	NA	**3,218,820**	NA	NA

b. Adults

Forecast	25%	50%	75%	90%
SStM	1,236,150	**921,820**	618,633	601,303
SEPB	863,704	**829,640**	580,460	454,570
SSM	NA	**3,067,171**	NA	NA

*probability that the actual run size will exceed the specified forecast.

Table 14. Barkley Sound sockeye stock and Robertson Creek coho marine survival deviations from 1974 – 2000.

Return year	Total stock	Deviations from 24 yr mean (1974-1997)	Coho brood year	Coho return year	Sockeye return year	Robertson Creek* coho smolt-to-adult survival (%) (1974-1996)	Devs from 23 year survival mean
1974	321315	-479985	1972	1975	1976	6.6	2.252
1975	420826	-380474	1973	1976	1977	7.7	3.352
1976	880540	79240	1974	1977	1978	7.2	2.852
1977	1399011	597711	1975	1978	1979	4.9	0.552
1978	344000	-457300	1976	1979	1980	8.8	4.452
1979	1088166	286866	1977	1980	1981	4.6	0.252
1980	961536	160236	1978	1981	1982	2.2	-2.148
1981	1349191	547891	1979	1982	1983	2	-2.348
1982	880261	78961	1980	1983	1984	5.7	1.352
1983	1504987	703687	1981	1984	1985	6.9	2.552
1984	1172004	370704	1982	1985	1986	2	-2.348
1985	669070	-132230	1983	1986	1987	3.9	-0.448
1986	300000	-501300	1984	1987	1988	2.9	-1.448
1987	635665	-165635	1985	1988	1989	1.8	-2.548
1988	849662	48362	1986	1989	1990	4.9	0.552
1989	460401	-340899	1987	1990	1991	9	4.652
1990	353910	-447390	1988	1991	1992	5.9	1.552
1991	1820145	1018845	1989	1992	1993	4.6	0.252
1992	996793	195493	1990	1993	1994	2.4	-1.948
1993	1279074	477774	1991	1994	1995	0.1	-4.248
1994	500000	-301300	1992	1995	1996	1.3	-3.048
1995	199293	-602007	1993	1996	1997	1.6	-2.748
1996	380123	-421177	1994	1997	1998	3	-1.348
1997	465237	-336063	1995	1998	1999	3.6	-0.748
1998	659745	-141555	1996	1999	2000	2.1	-2.248
1999	509353	-291947	1997	2000	2001	7.6	3.252
2000	321982	-479318	1998	2001	2002	7.6	3.22
2001	1017469	216169	1999	2002	2003	9.6	5.252
2002	1114971	313671	2000	2003	2004	4.7	.352
Mean	801300					4.347826	

* Data from Kadowaki and Holtby (1998). S98-5, Appendix Table 1. And Diana Dobson (unpublished observations)

Table 15. Relationships between deviations from average marine survival rates* of Robertson Ck coho in year n and deviations in year n+1 from the 24 year average return of sockeye (SRD's) for the 1984-1996 ($\mathbf{CLI_{13}}$) and 1972-1996 ($\mathbf{CLI_{25}}$) brood years.

		n	r2	prob.	Predicted deviation from mean sox. return	Total returns of sockeye expected in 2001
$\mathbf{CLI_{13}}$	(SRD's + 10^6)/ 10^6 = (0.163) (coho survival deviations + 10) - 0.577	12	0.74	< 0.01	915,000	1,716,300
$\mathbf{CLI_{25}}$	(SRD's + 10^6)/ 10^6 = (0.09) (coho survival deviations + 10) + 0.113	24	0.27	< 0.05	259,000	1,060,300

* assumes average survival rate for Roberston Ck coho is 4.35%
and that the 1999 coho brood year survival rate was 9.6%.

Appendix 1.

Overview of Management and 1996 Preseason Planning for Alberni Inlet Sockeye

Stock Background:

- Alberni Inlet sockeye consist of three stocks. Two stocks in the Somass River, Great Central Lake (GCL) and Sproat Lake. The Henderson Lake stock is the third stock in Alberni Inlet.
- The long term average target escapement is 350,000 sockeye into the Somass, plus 50,000 into Henderson Lake. Actual Somass River escapement has historically (1980-95) ranged from 168,000 in 1995 to 650,000 in 1991. The average escapement was 356,000 during this period. A stated objective for management of these stocks is to provide contrast in the escapements in order to determine an optimal target (PSARC document 89-13).
- The average run size of Somass River sockeye was 850,000 from 1980-95 with a range of 200,000 to 1,800,000. The average annual total catch during this period was 525,000 sockeye.

1996 Stock Forecast:

- The 1996 forecasted return to Barkley Sound is 278,740 sockeye including 252,430 to the Somass River system and 26,310 to Henderson Lake. This estimate is based on the low marine survival rate of 2.5% in the Survival Stanza Method (SStM). Salmon stocks from the west coast Vancouver Island are generally depressed due to poor ocean conditions associated with El Nino events starting in 1992.

Harvest Management Plan:

- The allowable catch (TAC) is based on a harvest rate strategy (Table 1) which provides small harvests at low run sizes above a minimum run size and increasing harvests based on an increasing harvest rate above this floor level. Under this plan, escapements are expected to range from 180,000 to 600,000 and average 350,000 – 400,000.
- The minimum escapement level has been set at 100,000 sockeye, including 50,000 for each system (GCL and Sproat). However, achieving these goals may be affected by 1) uncertainties in run size estimation, 2) uncertainties in biological factors associated with spawning (e.g. high prespawn mortality), and 3) variation in run size between the Sproat and Great Central systems. Consequently, a minimum combined run of 200,000 was established to ensure that escapements above the minimum level were achieved. Below the 200,000 combined run into the Somass, the harvest management plan allowed no fisheries.
- Generally, this harvest management plan is more conservative than historic management. In 10 of 15 years from 1980-94, the total allowable catch under the current plan is less than the actual historic exploitation.

Allocation:

- Within the framework of the Harvest Management Plan, the following allocation rules have been formulated. The objective of this allocation plan is to incorporate the variability in sockeye returns into the annual native catch (share in large runs and contribute to the conservation of small runs).
- Native fisheries (Tseshaht and Opetchesaht): By agreement between DFO and the Tseshaht First Nation and the Opetchesaht First Nation, there is a combined native base harvest of 20,000 sockeye if the run size is estimated to be greater than 200,000. In addition, these First nations will receive 8% of the TAC prescribed under the Harvest Management Plan. Under this agreement, sale of these sockeye is permitted by the Tseshaht and Opetchesaht First Nations.
- Assessment: There is an ongoing cost of assessment, including test fisheries and in-river and in-lake sampling, which will range from 3,000 to 20,000 sockeye. The cost of assessment will be minimized when run sizes are expected to be less than 350,000 sockeye.
- Sport Fisheries: The DFO recognizes the importance of the sockeye sport fishery to the local economy of Port Alberni and area. Consequently, the sport fishery is provided initial access to the sockeye run, after native and assessment fisheries, but within the total allowable catch determined from the Harvest Management Plan framework. Daily bag and possession limits, as well as area closures, will be instituted on an annual basis to limit total catch and distribute catch over the entire season.
- Commercial Fisheries: Commercial fisheries will commence when run sizes are estimated to be greater than 400,000. If preseason forecasts suggest greater than 400,000 then commercial gillnet fisheries will be initiated in mid to late June to provide early season assessment information.

1996 Inseason Adjustment:

- Escapement assessment began May 14 on the Sproat River and June 5 in GCL. The seine test fishery is scheduled to commence July 2 and continue at 2 days per week for 4 weeks. Hydro-acoustic transects will also be conducted. Catch monitoring for the sport and native fisheries is in place. Monitoring of the Hobiton Lake sockeye stock, to provide an indication of run timing for Alberni Inlet sockeye, is also underway.
- The first run re-forecast of Somass sockeye run size will be announced July 11, which corresponds to the normal peak timing of migration. The precision of the re-forecast increases each week as more information becomes available and the peak of migration is identified.
- Changes in run size will result in management actions taken to achieve the total catch allowable (TAC) under corresponding harvest rate in the harvest management plan.

Appendix 1. Table of Alberni Inlet Sockeye Allowable Harvest (approved 1995)

Somass Run Size		Proposed			Proposed		TF base=	20	8%	
Range	Midpoint	Low-end harvest rate	Escape add-on	Total allowable catch	Total harvest rate	Escape	TF base	TF hr	TF total	Rem TAC
	100				0%	100				0
<200	200				0%	200				0
201-250	225	10%	0	23	10%	203	20	8%	22	1
251-350	300	15%	0	45	15%	255	20	8%	24	21
351-450	400	20%	0	80	20%	320	20	8%	26	54
451-550	500	25%	0	125	25%	375	20	8%	30	95
551-650	600		50	200	33%	400	20	8%	36	164
651-750	700		50	300	43%	400	20	8%	44	256
751-850	800		50	400	50%	400	20	8%	52	348
851-950	900		100	450	50%	450	20	8%	56	394
951-1050	1000		100	550	55%	450	20	8%	64	486
1051-1150	1100		100	650	59%	450	20	8%	72	578
1151-1250	1200		150	700	58%	500	20	8%	76	624
1251-1350	1300		150	800	62%	500	20	8%	84	716
1351-1450	1400		150	900	64%	500	20	8%	92	808
1451-1550	1500		150	1000	67%	500	20	8%	100	900
1551-1650	1600		200	1050	66%	550	20	8%	104	946
1651-1750	1700		200	1150	68%	550	20	8%	112	1038
1751-1850	1800		250	1200	67%	600	20	8%	116	1084
1851-1950	1900		250	1300	68%	600	20	8%	124	1176
1951+	2000		250	1400	70%	600	20	8%	132	1268

note: all sockeye numbers above in thousands

note: run size midpoints and range include "jacks"

note: TF is Tsu-ma-uss Fisheries (Tseshaht and Opetchesaht); TF allocation is 8% of total TAC on top of 20k base.

note: Rem TAC is remaining total allowable catch for sport, commercial, and test fisheries.

Preseason allowable exploitations and catch by user group.

	Forecast	Desired harvest	Ttl TAC	Expected escape.	TF base	TF hr	TF TAC	rem TAC
1995	252,056	15%	37,808	214,248	20,000	8%	23,025	14,784
1996	252,400	15%	37,860	214,540	20,000	8%	23,029	14,831

Actual end of season harvest/escapement accounting.

	Escape.	Native	Sport	Test fish. Catch	Comm.	Ttl Catch	Ttl Run	Actual harvest
1995	167,634	23,782	6,519	914	0	31,215	198,849	15.70%

Figure 1 Location of Barkley Sound and boundaries used in managing salmon fisheries there.

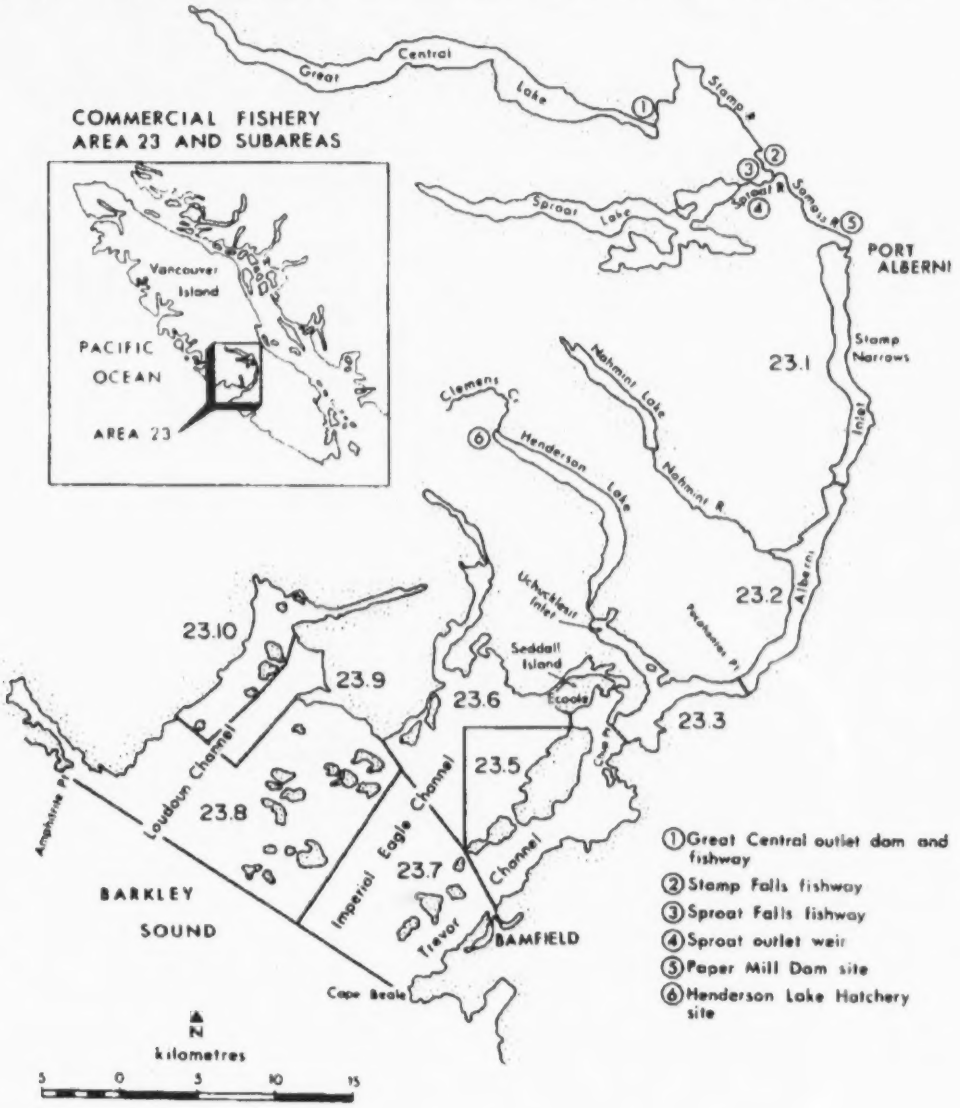

Figure 2. Sockeye Returns (1000's) to Barkley Sound 1974-2002